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EXPERIMENTAL AND THEORETICAL STUDIES OF TIME-AVERAGED AND TIME-RESOLVED ROTOR HEAT TRANSFER

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CUBRC efforts in support of the SSME structural durability program have concentrated on obtaining detailed time-averaged and time-resolved (or phase-locked) measurements on a full-scale rotating turbine both with and without cold gas injection and on theoretical studies designed to improve the prediction capability for these turbine flows. The experimental efforts have concentrated on use of the Garrett TFE 731-2 hp turbine. However, it has been possible to apply the theoretical efforts to predicting heat-flux distributions obtained for two additional turbines - i.e., (1) the Garrett low aspect ratio turbine (LART) and (2) the Teledyne 702 turbine. In performing these calculations, the ground rules have been that only the turbine inlet parameters and the turbine geometry can be altered in performing the calculations for the respective turbines.

EXPERIMENT

The experimental technique is the short-duration, shock-tunnel approach, in which fast-response, thin-film resistance thermometers are used to measure surface temperature histories at prescribed locations on the turbine component parts. Heat-flux values are then inferred from the temperature histories by using standard data reduction procedures. The turbine being used is the Garrett TFE 731-2 hp stage, and both the nozzle guide vanes and the rotor blades are heavily instrumented with thin-film heat-flux gauges. A detailed description of this instrumentation was previously given (ref. 1) at the 1985 Structural Durability meeting. Depending on how the data from a particular heat-flux gauge are recorded, one can get either time-resolved (or phase-locked) or time-averaged results. Both types of data are illustrated in this presentation.

PREDICTIONS

It is important to be able to predict both the time-resolved and the time-averaged heat-transfer distributions described previously. For the time-averaged prediction, a wide variety of predictive techniques have been developed that range from simple flat-plate correlations to computer codes based on the full three-dimensional Navier-Stokes equations. Between these limits, there exists a substantial body of analytical and numerical methods which account for most of the dominant physical phenomena while still being sufficiently convenient for use by a large fraction of those involved in the field. As part of this NASA effort, several of these midrange methods have been assembled to perform state-of-the-art predictions for several different

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turbines. The specific turbines for which these predictions have been performed are (1) the Garrett TFE 731-2, (2) the Garrett low aspect ratio turbine (LART), and (3) the Teledyne 702-hp turbine. Results from the first two turbines were reported in reference 2 and from the third in reference 3. Typical results are given in figures 1 and 2.

Predicting the unsteady flow field is a significantly less developed area of research than is predicting the steady state flow field. Some effort is ongoing within CUBRC to analyze and interpret the unsteady thermal loads on a typical rotating turbine. At this time, the ability to perform phase-locked heat-flux measurements on a turbine rotor is more advanced than the ability to predict same. Figure 3 is a typical phase-locked heat flux distribution obtained at approximately 15 percent wetted distance on a turbine blade suction surface for a rotation speed of 27,000 rpm.

REFERENCES

1. Dunn, M.G.; Rae, W.J.; and George, W.K.: Experimental Measurements and Analysis of Heat Transfer and Gas Dynamics in a Rotating Turbine Stage. Structural Integrity and Durability of Reusable Space Propulsion Systems, NASA CP-2381, 1985, pp. 49-52.

2. Rae, W.J. et al.: Turbine-Stage Heat Transfer: Comparison of Short-Duration Measurements with State-of-the-Art Prediction. AIAA Paper 86-1465, June 1986.

3. Dunn, M.G.; and Chupp, R.E.: Time-Averaged Heat-Flux Distributions and Comparison with Prediction for the Teledyne 702 HP Turbine Stage. To be presented at the 32nd International Gas Turbine Conference, Anaheim, CA, June 1987.

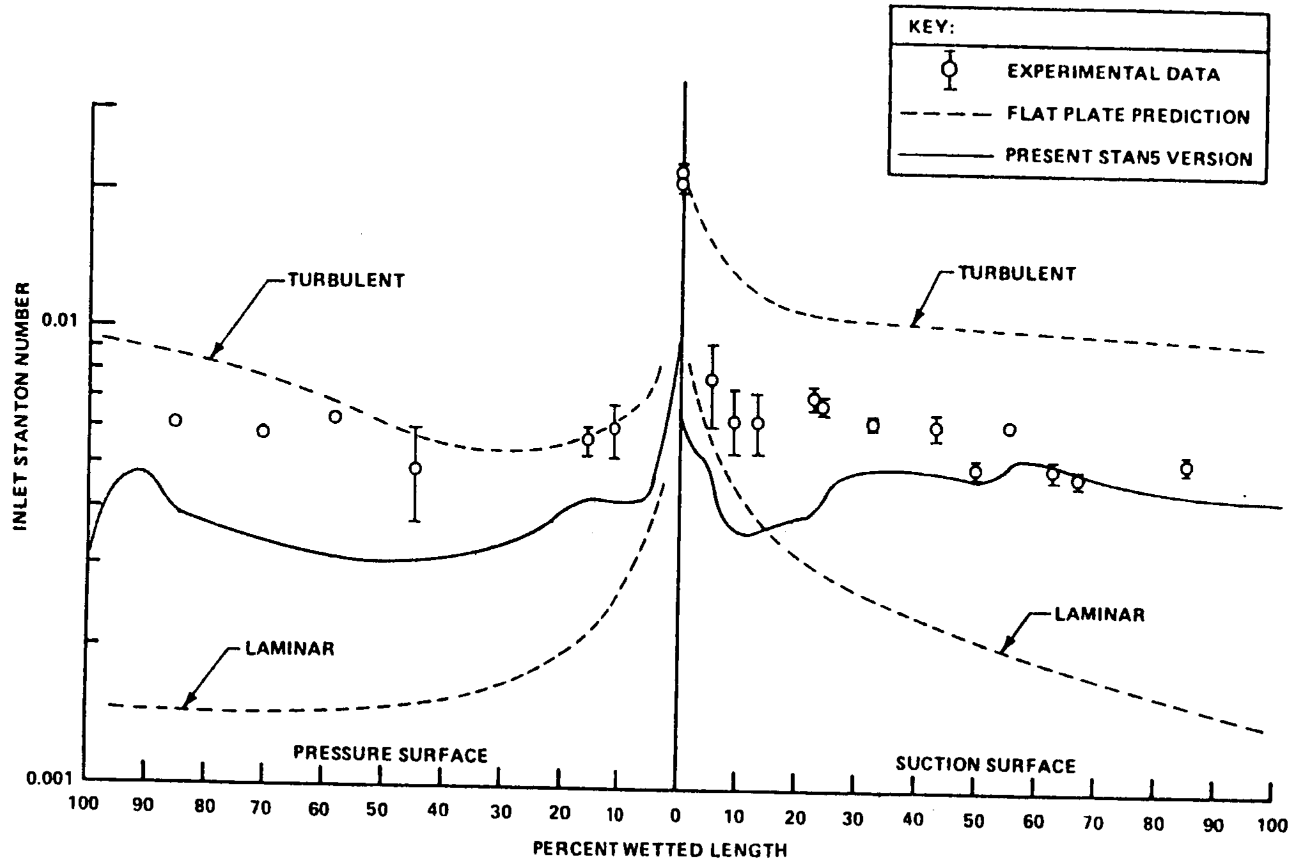

Figure 1.- COMPARISON OF EXPERIMENTAL DATA WITH PREDICTION FOR ROTOR BLADE OF TFE 731-hp TURBINE.

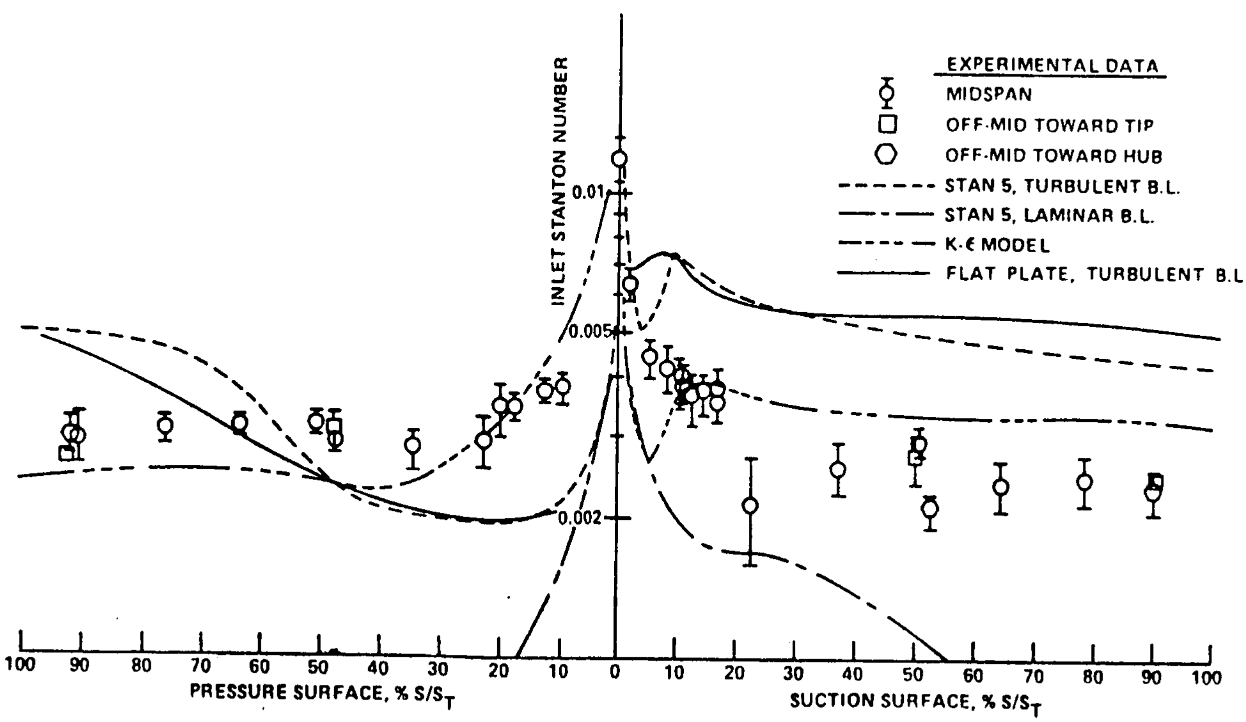

Figure 2. – STANTON NUMBER DISTRIBUTION FOR TELEDYNE 702 BLADE.

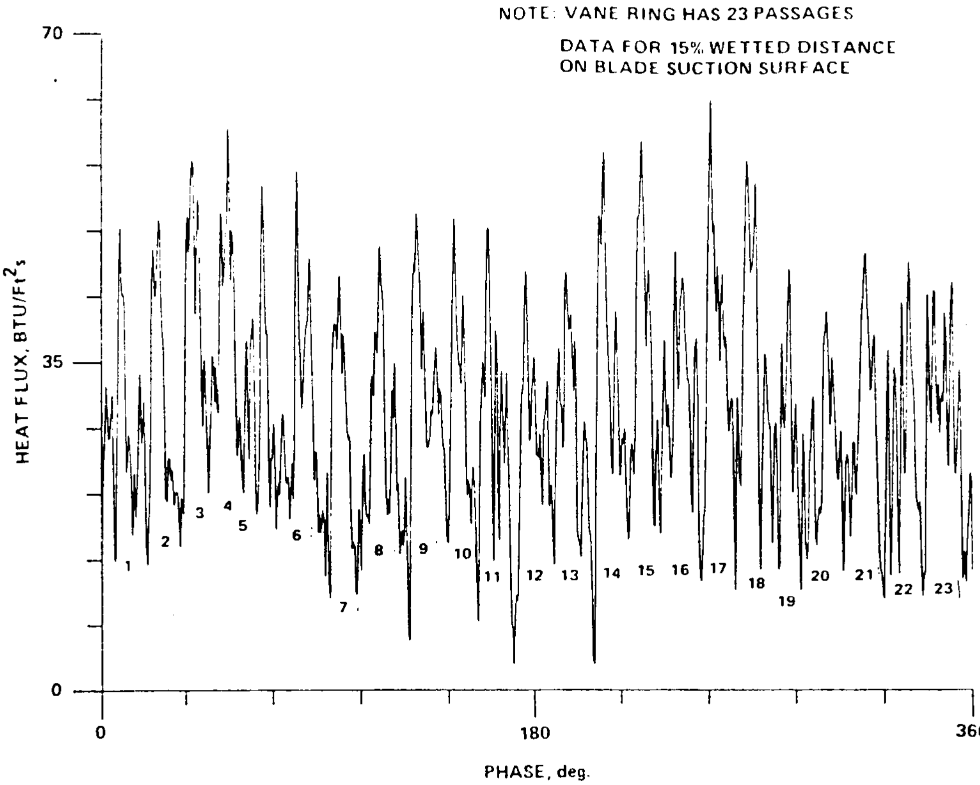

Figure 3. – HEAT-FLUX HISTORY FOR ONE REVOLUTION CALCULATED FROM THREE-POINT FILTERED TEMPERATURE SIGNAL.